# CLAIMS

1. A neural network, comprising several nodes forming at least two layers a first one of which is a so called input layer and the last of which layers is a so called output layer, the input layer nodes forming inputs for entering the input data of a database and the output layer nodes forming outputs channels for furnishing output data which are the results of the elaboration of the input data, connection being provided between the nodes of the input layer and the nodes of the output layer, each node of the output layer carrying out a transformation of the input data received from the input layer into output data which transformation comprises a first transformation step comprising at least a sub-step consisting in summing the input data received from the input nodes to the said output nodes by weighting the said input data and a second transformation step which transforms non linearly the results obtained by the first transformation step the output data obtained by the said transformation carried out in an output node being the output data

characterised in that

in each output node the first transformation step comprises two sub-steps a first sub-step being a non linear transformation function of the input data received by the output nodes from the input nodes and the second sub-step being the summing step of the said non linearly transformed input data in the said first sub-step.

2. An artificial neural network according to claim 1 comprising an input layer having a predetermined

number of input nodes and an output layer having a predetermined number of output nodes, characterised in that between the input and the output layer there is provided at least one further layer of nodes, so called hidden layer, or more than one hidden layers, the nodes of this hidden layer being connected by weighted connection to the input nodes of the input layer and to the nodes of a further hidden layer when more than one hidden layer is provided or to the output nodes of the output layer if only one hidden layer is provided, each node of the at least one hidden layer or of the more than one hidden layers and the nodes of the output layer carrying out a transformation of the input data received from the input layer or from a preceding hidden layer into output data which transformation comprises a first transformation step consisting in two subsequent sub-steps, a first sub-step consisting in a non linear transformation function of the input data received by the output nodes or by the nodes of a hidden layer from the input nodes of the input layer or by the nodes of the preceding hidden layer and the second sub-step consisting in summing the said input data being non linearly transformed in the said first sub-step by further weighting the said non linearly transformed input data and a further second transformation step being carried out which transforms non linearly the results obtained by the first transformation step, the output data obtained by the said transformation carried out in the said nodes being the output data if the nodes are the output nodes of the output layer or the input data furnished from the nodes of a hidden layer to the nodes of a following

hidden layer or to the output nodes of the output layer.

3. An artificial neural network according to claim 1 in which the input data of the nodes of the input layer consist in the input data of the database, while the output data of the nodes of the input layer are furnished to the nodes of the output layer or to the nodes of the first hidden layer or to the at least one hidden layer as input data of the nodes of these layers and the output data of the output layer consist in the elaboration result of the artificial neural network.

4. An artificial neural network according to one or more of the preceding claims characterised in that the first non linear transformation sub-step of the input data carried out by a node comprises a transformation of the input data by means of a sinusoidal function and the second transformation sub-step consist in the sum of the input data after transformation by the sinusoidal function, i.e. after having carried out the said first transformation sub-step.

5. An artificial neural network according to one or more of the preceding claims, characterised in that each node of the at least one hidden layer and of the output layer comprises several input channels for different input data;

to each channel being associated

a receiver unit for carrying out the first non linear transformation sub-step of the first transformation step;

a summation unit being further provided having an input connected to the outputs of the receiver unit of each channel and for carrying out the second

transformation sub-step of the first transformation step by summing the non linearly transformed input data of each channel to a value

and a non linear transformation unit having an input connected to an output of the summation unit for carrying out the second transformation step by non linear filtering of the value obtained by the first transformation step and furnishing the output value of the node which is the input value of the nodes of a following hidden or of the output layer.

6. An artificial neural network according to one or more of the preceding claims, characterised in that input data consist in a predetermined number of variables in a input data variable space each variable being defined by coordinates in the input data space and each coordinate in the input data space is non linearly transformed in the first transformation step in a corresponding variable value which is made dependent by the spatial position of the coordinate value with respect a spatial wave of given wavelength, this dependence consisting in multiplying the input coordinate values, by the wavelength of a sinusoidal wave which are then transformed into the same value, the wavelength on each input coordinate being tuned during the learning phase.

7. An artificial neural network according to one or more of the preceding claims characterised in that the transformation of the input data carried out by each node is defined by the following equation

$$x_j^{[s]} = F\left(G\left(w_{ji}^{[s]}, x_i^{[s-1]}\right)\right) \quad (4)$$

where the *non linear* transformation *F(·)* is the non linear filtering function of the second transformation

step and $G(\cdot)$ is the combination of the non linear transformation function of the first transformation sub-step and of the second linear transformation sub-step consisting in the sum of the non-monotonically, sinusoidal processed weighted inputs according to the following function:

$$G\left(w_{ji}^{[s]}, x_i^{[s-1]}\right) = \sum_{i=0}^{n} \sin\left(w_{ji}^{[s]} \cdot x_i^{[s-1]}\right) \qquad (5)$$

where

$[s]$ : the generic layer of the network, with s=1 for the input layer and increasing values for the hidden and output layers;

$x_j^{[s]}$ : the output variable of the $j-th$ node in layer $[s]$;

$x_i^{[s-1]}$ : the $i-th$ input to the generic node in layer $[s]$ from the $i-th$ node in layer $[s-1]$;

$x_0^{[s-1]}$ : a "false" input to the generic node in layer $[s]$, artificially introduced to represent, in a mathematically convenient way, a useful threshold value which is usually fixed to 1.

$w_{ji}^{[s]}$ : the weight on the connection joining the $i-th$ node in layer $[s-1]$ to the $j-th$ node in layer $[s]$;

$n$ : the number of input to the node.

8. An artificial neural network according to claim 7, characterised in that each node carries out a transformation of the input data according to the following function:

$$x_j^{[s]} = F\left(\sum_{i=0}^{n} \sin\left(w_{ji}^{[s]} \cdot x_i^{[s-1]}\right)\right) \quad (6)$$

The sine function introducing a qualitative process as each weight $w_{ji}^{[s]}$ plays as a *2π / wavelength* parameter in the *i-th* coordinate of the input space of the *j-th* node of the *s-th* layer.

9. An artificial neural network according to one or more of the preceding claims characterised in that the second non linear transformation step is carried out by means of a sigmoid function.

10. An artificial neural network according to one or more of the preceding claims characterised in that it is a multilayer Back propagation neural network comprising a forward phase and a learning phase which uses a gradient descent principle;

the forward phase being defined by the following equations:

A first harmonic transformation step furnishing the transformed net input value I where

$$I_j^{[s]} = \frac{2\pi}{n} \sum_{i=0}^{n} \sin\left(w_{ji}^{[s]} \cdot x_i^{[s-1]}\right) \quad (7)$$

A second non linear transformation step by means of a so called activation function $f\left(I_j^{[s]}\right)$ determining the output of the node according to the equation:

$$x_j^{[s]} = f\left(I_j^{[s]}\right) = f\left(\frac{2\pi}{n}\sum_i \sin\left(w_{ji}^{[s]} \cdot x_i^{[s-1]}\right)\right) \tag{8}$$

the learning phase being defined by the following equations:

The gradient descent principle

$$\Delta w_{ji}^{[s]} = -lcoef \cdot \frac{\partial E}{\partial w_{ji}^{[s]}} \tag{10}$$

with usual Global Error functions, the error on each node is evaluated by defining the local according to the equation:

$$e_j^{[s]} = -\frac{\partial E}{\partial I_j^{[s]}} \tag{12}$$

Thus obtaining

$$\Delta w_{ji}^{[s]} = -lcoef \cdot \frac{\partial E}{\partial w_{ji}^{[s]}} =$$

$$= -lcoef \cdot \frac{\partial E}{\partial I_j^{[s]}} \cdot \frac{\partial I_j^{[s]}}{\partial w_{ji}^{[s]}} = \tag{13}$$

$$= lcoef \cdot e_j^{[s]} \cdot \frac{\partial}{\partial w_{ji}^{[s]}}\left(\frac{2\pi}{n}\sum_k \sin\left(w_{jk}^{[s]} \cdot x_k^{[s-1]}\right)\right) =$$

$$= lcoef \cdot e_j^{[s]} \cdot \frac{2\pi}{n} x_i^{[s-1]} \cdot \cos\left(w_{ji}^{[s]} \cdot x_i^{[s-1]}\right)$$

and for determining the weights correction value, the local error $e_j^{[s]}$ being calculated as:

For the output layer:

$$e_j^{[out]} = -\frac{\partial E}{\partial I_j^{[out]}} =$$

$$= -\frac{\partial E}{\partial x_j^{[out]}} \cdot \frac{\partial x_j^{[out]}}{\partial I_j^{[out]}} = \qquad (14)$$

For the other layers:

$$e_j^{[s]} = -\frac{\partial E}{\partial I_j^{[s]}} =$$

$$= -\frac{\partial E}{\partial x_j^{[s]}} \cdot \frac{\partial x_j^{[s]}}{\partial I_j^{[s]}} =$$

$$= -f'\left(I_j^{[s]}\right) \cdot \sum_k \left( \frac{\partial E}{\partial I_k^{[s+1]}} \cdot \frac{\partial I_k^{[s+1]}}{\partial x_j^{[s]}} \right) = \qquad (15)$$

11. An artificial neural network according to claim 10, characterised in that

the activation function of the forward phase $f\left(I_j^{[s]}\right)$ is the sigmoidal fucntion:

$$x_j^{[s]} = sigm\left(I_j^{[s]}\right) = \frac{1}{1+e^{-I_j^{[s]}}} \qquad (9)$$

the error function of the learning phase is the Medium Square Error function:

$$E = \frac{1}{2} \cdot \sum_{k=1}^{m} \left( t_k - x_k^{[out]} \right)^2 \qquad (11)$$

the weight correction value for the output layer becoming

$$-\left( \frac{\partial}{\partial I_j^{[out]}} f\left(I_j^{[out]}\right) \right) \cdot \left( \frac{\partial}{\partial x_j^{[out]}} \left( \frac{1}{2} \sum_{k=1}^{m} \left( t_k - x_k^{[out]} \right)^2 \right) \right) =$$

$$= f'\left(I_j^{[out]}\right) \cdot \left( t_j - x_j^{[out]} \right)$$

the weight correction value for the other layers becoming

$$- f'\left(I_j^{[s]}\right) \cdot \sum_k \left( - e_k^{[s+1]} \cdot \frac{\partial}{\partial x_j^{[s]}} \left( \frac{2\pi}{n} \sum_h \left( \sin\left( w_{kh}^{[s+1]} \cdot x_h^{[s]} \right) \right) \right) \right) =$$

$$= f'\left(I_j^{[s]}\right) \cdot \frac{2\pi}{n} \sum_k \left( e_k^{[s+1]} \cdot w_{kj}^{[s+1]} \cdot \cos\left( w_{kj}^{[s+1]} \cdot x_j^{[s]} \right) \right)$$

12. An artificial neural network according to one or more of the preceding claims, characterised in that the input nodes of the input layer carry out a first non linear transformation step and a second non linear transformation step of the input data received by being provided with the following units:

a receiving channel for input data

a receiver unit associated to the said receiving channel for carrying out the first non linear transformation sub-step of the first transformation step as defined in the previous claims;

a summation unit for carrying out the second transformation sub-step of the first transformation

step by summing the non linearly transformed input data of each channel to a value as defined in the previous claims;

and a non linear transformation unit for carrying out the second transformation step by non linear filtering of the value obtained by the first transformation step as defined by the previous step and furnishing the output value of the input nodes node which is the input value of the nodes of a following hidden or of the output layer.